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(71) Applicant: SONY CORPORATION
Tokyo (JP)

(72) Inventor: Suzuki, Mitsuhiro
Shinagawa-ku, Tokyo (JP)

(74) Representative: Nicholls, Michael John
J.A. KEMP & CO.
14, South Square
Gray's Inn
London WC1R 5LX (GB)

(54) Resource allocation in a multi-user, multicarrier mobile radio system

(57) In even code division multiple access method (CDMA) considered to be suitable for radio transmission using mobile stations such as a cellular phone or the like, at present it is difficult to secure a strict orthogonal relationship, so that received signals cannot be separated from each other completely, thereby other mobile stations being an interfering source. Further, if an application band width for use is defined, the other band widths cannot be applied. The multi-carrier modulation section places a plurality of carriers continuously within a preliminarily allocated band and modulates the individual carriers separately. An adder synthesizes a plurality of the carriers modulated by the multi-carrier modulation section. An antenna transmits a synthesized output from the adder.

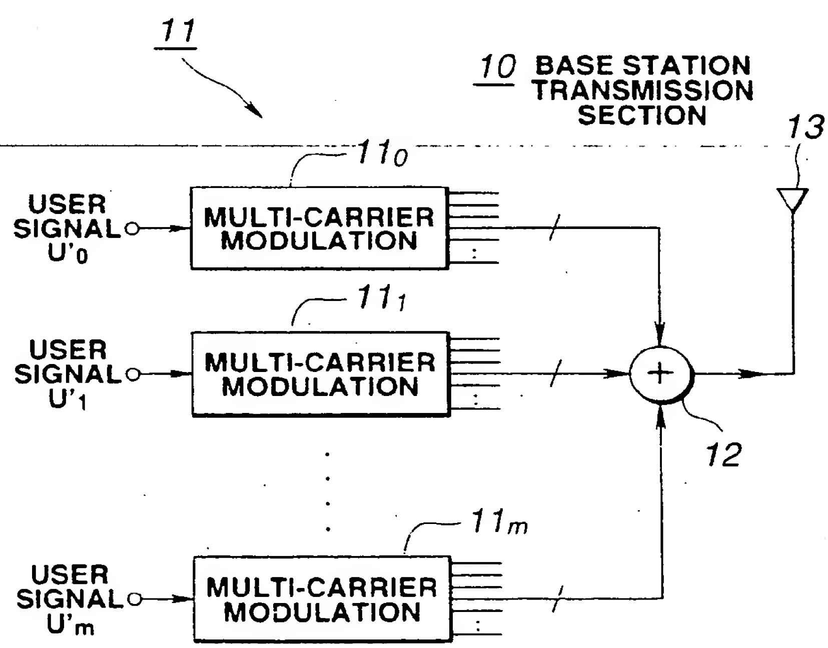


FIG.2

EP 0 786 890 A2

Description

This invention relates to a communication resource allocation method and apparatus for allocating signals of plural users in a predetermined band for transmission.

Recently, satellite transmission, mobile transmission or the like uses communication resource allocation method wherein a plurality of earth stations or subscriber stations join a single transponder or base station for mutual exchange of information for communication. For example, in communication resource allocation for mobile transmissions, a single base station is commonly utilized by a plurality of mobile stations (users). Thus, a variety of methods have been conceived to avoid interference between respective mobile stations. For this purpose, the methods of frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA) are currently available.

Of these methods, CDMA is a communication resource allocation methods in which a particular code is allocated to each of mobile stations, a modulated wave on the same carrier is spread in the form of spectrum by this code and transmitted to the same base station and a receiving side encodes respective waves by synchronizing to identify a desired mobile station.

That is, the base station occupies all the band by spread spectrum and transmits to respective mobile stations in the same interval of time and by use of the same frequency band. Then, each mobile station de-spreads signals having a fixed spread band width transmitted from the base station to fetch an appropriate signal. Additionally, the base station identifies respective mobile stations by mutually different codes for spreading.

CDMA makes it possible to communicate by each direct call if the particular code is determined between the base station and each of respective mobile stations. Additionally, CDMA provides excellent secrecy in communication and therefore suitable for radio transmission using a mobile station, such as a cellular phone or the like.

CDMA makes it difficult to place signals transmitted from different mobile stations in strict orthogonal relationship, so that they cannot be separated from each other completely, whereby other mobile stations are interfering sources. Further, if an application band width is defined, other band widths cannot be applied.

For example, FIG. 1 illustrates a model for extracting, by de-spreading, a particular user s signal from eight mobile station (user) signals multiplexed by coding. If it is intended to extract, by de-spreading, U_0 from eight user signals U_0 - U_7 multiplexed by coding, although user signal U_0 can be extracted, the other seven user signals U_1 - U_7 handled by the same base station interfere. As a result, as shown in FIG. 1B, noise from the other signals U_1 - U_7 ride on the signal U_0, so deteriorating S/N characteristics. Thus, radio transmission using the CDMA has a narrow service area because radio wave transmission is lowered due to this deterioration. Further, because interference using the other users can be suppressed only by a spreading gain obtained in a process of spectrum de-spreading, the users (mobile stations) capable of connecting to the base station is limited so that the capacity of channel is reduced.

The spreading band width is usually fixed and the number of users which can be multiplexed is limited, therefore the CDMA cannot flexibly cope with respective conditions in frequency allocation different depending on countries. Thus, only a relatively narrow band width can be defined, so that a maximum user rate is also limited.

According to the present invention invention, there is provided an allocation method comprising:allocating plural carriers continuously in a predetermined band; and allocating some numbers of said carriers continuously as a carrier group in accordance with information to be transferred.

The hereinafter described embodiments of the present invention can provide a communication resource allocation method and apparatus wherein separation of signals among respective users can be achieved completely so as to prevent deterioration of such characteristics as S/N or the like, the number of users which can be multiplexed can be secured to its maximum extent depending on the band width and transmission rate can be changed.

Hereinafter, a non-limitative embodiment of the communication resource allocation method and apparatus according to the present invention will be described with reference to the accompanying drawings, in which:

FIGS. 1A, 1B are diagrams showing multiple access by CDMA and the limit of the multiple access.

FIG. 2 is a block diagram showing a schematic construction of an embodiment of a communication resource allocation method and apparatus according to the present invention.

FIG. 3 is a block diagram showing a detailed construction of the major parts of the above embodiment.

FIG. 4 is a block diagram showing the construction of a mobile station receiving signals transmitted from the above embodiment.

FIGs. 5A, 5B are diagrams showing multiple access conducted by the above embodiment.

FIG. 6 is a diagram showing a placement of carriers within a band and allocation thereof to user according to the above embodiment.

FIG. 7 is a diagram showing variable transmission rates according to the above embodiment.

FIG. 8 is a diagram for explaining the operation of the present embodiment using the OFDM processing.

FIG. 9 is a diagram showing a case in which allocation of frequency is wide.

FIG. 10 is a diagram showing a case in which allocation of frequency is narrow.

FIG. 11 is a diagram showing a case in which allocation of frequency is particularly wide.

FIG. 12 is a diagram showing a case in which the present invention is applied to broadcasting equipment.

FIG. 13 is a diagram showing a broadcasting receiver.

FIG. 14 is a diagram showing a communication terminal apparatus.

FIG. 15 is a diagram showing an example of base station equipment corresponding to a mobile station such as a cellular phone or the like.

FIG. 16 is a diagram showing an example of a computer apparatus accessing an internet or the like through optical fiber or telephone line or the like.

FIG. 17 is a diagram showing an example of a network server to be connected to internet or the like.

FIG. 18 is a diagram showing an example of application of the present invention to internet.

According to this embodiment, the communication resource allocation method and apparatus of the present invention is applied to a base station 10, as shown in FIG. 2, which has multiple access to a plurality of user signals for transmission with mobile stations, such as cellular phone or automobile telephone.

This base station 10 includes a multi-carrier modulation section 11 for placing a plurality of carriers continuously within a preliminarily allocated band and for dividing and modulating the carriers, and an adder 12 for synthesizing a plurality of the carriers modulated by this multi-carrier modulation section 11. Then, a synthesized output from the adder 12 is transmitted through an antenna 13.

That is, the base station 10 conducts communication resource allocation for multiple access by dividing a plurality of the carriers, placed continuously within a preliminarily allocated band having a predetermined width, for respective mobile stations. This communication resource allocation method is called band division multiple access method (BDMA) here.

This BDMA is different from frequency division multiple access (FDMA). The FDMA refers to a communication resource allocation method in which a relatively low transmission rate is determined and a plurality of carriers which are not always sequential are placed on frequency axis. On the other hand, the BDMA refers to a communication resource allocation method in which, as described above, a relatively wide band is initially allocated to a base station and then divided to respective mobile stations under the base station and is different from the above FDMA.

Here, the multi-carrier modulation section 11 contains a plurality of (m+1) multi-carrier modulators 11_0, 11_1 ··· 11_m depending on user signals U'_0, U'_1 ··· U'_m divided for respective users.

The construction of the multi-carrier modulators 11_0, 11_1, ··· 11_m will be described with reference to FIG. 3. FIG. 3 shows, for example, the construction of the multi-carrier modulator 11_0.

In the multi-carrier modulator 11_0, carrier allocators 20 allocates a user signal U'_0 to a plurality of carriers and the allocated signals are modulated by carrier modulation circuits 21_1, 21_2, ··· 21_n. The outputs modulated by the respective carrier modulation circuits 21_1, 21_2, ··· 21_n are supplied to the adder 12.

The carrier modulation signals transmitted from an antenna 13 are received by mobile stations 30 which are respective users as shown in FIG. 4. If this mobile station receives, for example, the carrier modulation user signal U_0, the respective carrier demodulation circuits 32_1, 32_2 ··· 32_n of the carrier demodulation section 32 demodulate respective carrier modulation signals. Then, the respective demodulation signals are synthesized by a signal synthesizer 33.

The mobile station 30 fetches the carrier modulation user signal U_0 by filtering, by means of a band-pass filter, from a plurality of carrier modulation signals transmitted from the base station by communication resource allocation method of the BDMA, for example, 16 carrier modulation user signals U_0, U_1, ··· U_{15} shown in FIG. 4A, in such a manner as shown in FIG. 5B. This is made possible by carrier modulation in which the base station 10 divides a band according to the BDMA. In this case, separation of the respective carrier modulation signals among users can be achieved by the filter completely. That is, the other carrier modulation user signals U_1, ··· U_{15} handled by the same base station do not become an interference source. Thus, no other carrier modulation user signals rides on a fetched carrier modulation user signal U_0, thereby preventing deterioration of S/N ratio.

Further, because there occurs no interference from other users, the base station can determine the number of users which can be multiplexed depending on a predetermined band width.

Meanwhile, according to this embodiment, as shown in FIG. 6, narrow band carriers are placed continuously in respective band of each of user signal carriers allocated to the base station 10 by the multi-carrier modulation section 11. Namely, in each of the bands of respective user signals U_0, U_1, ··· U_{15} shown in FIG. 6A, the multi-carrier modulation section 11 places the carrier C as shown in FIG. 6B.

Here, although the number of the carriers to be allocated to a single user is assumed to be 10, it is permissible that the number is one minimum.

Further, the multi-carrier modulation section 11 places a single carrier having 0 power as a guard band G on the border of each band to minimize an interference of a band in the neighborhood between users placed nearby. Here, if the influence of an interference by the band in the neighborhood is less, it is permissible that the carrier having 0 power does not exist, and if the influence thereof is excessive, a plurality of the carriers having 0 power may be placed.

Further, as shown in FIG. 7, the multi-carrier modulation section 11 is capable of changing transmission rate by

making the number of the carriers C allocated to the users variable. That is, the multi-carrier modulation section 11 is capable of making the division width of a single band variable by dividing the band to an arbitrary number of the carriers C depending on user condition so as to achieve modification of the transmission rate. Division of the carriers C in the carrier modulation user signal U0 and the carrier modulation user signal U_1 shown in FIG. 7A can be achieved by mutually different numbers as shown in FIG. 7B. Therefore, the carrier modulation user signal U_0 can be transmitted by twice the transmission rate of the carrier modulation user signal U_1.

Further, the multi-carrier modulation section 11 may place the plurality of the above carriers continuously as shown in FIG. 8 by orthogonal frequency division multiplex (OFDM) processing. Referring to FIG. 7, w(f) indicates a waveform indicating an energy on the frequency axis and B indicates a carrier distance. Here, the OFDM will be described below.

In ordinary modulation, as indicated by the following expression (1), pulse waveforms each represented by h(t) are placed on time axis, information symbol of xk is posed thereon and the pulse waveforms are slid with respect to each other to be overlapped.

[Expression 1]

$$x(t) = \sum_k x_k\, h(t-kT) \quad \cdots (1)$$

As a result of Fourier transformation of this expression, the expression (2) is obtained as shown below.

[Expression 2]

$$x(f) = \sum_k x_k H(f) \exp(-j2\pi kfT) \quad \cdots (2)$$

Then, in this expression (2), time axis t is replaced with frequency axis f. That is, f is replaced with t, symbol time T is replaced with carrier distance B and waveform generation filter H(f) is replaced with time window (t). As a result, the expression (3) can be obtained as shown below.

[Expression 3]

$$x(t) = \sum_k x_k \exp(-j2\pi kBT)\, w(t) \quad \cdots (3)$$

This expression (3) presents modulated waves of the unit of an hour under the OFDM.

That is, this expression (3) indicates that a modulation symbols of xk are placed on frequency axis, they are modulated by the multi-carrier represented by exp(-j2πkBt), and that time window w(t) limits the modulation because the modulation symbols xk modulated continuously are not located on time axis.

In ordinary multi-carriers, because respective narrow band carrier signals are filtered, the amount of corresponding processing is large and some guard bands are necessary for each of the carriers, so that the efficiency of use of frequency is reduced slightly.

Then, with use of the above OFDM processing, assuming that transmission rate for each of the carriers is B[Hz], the band width necessary therefor can be also B[Hz].

Because, in the OFDM, rapid arithmetic operation using rapid Fourier transformation is possible, this can achieve a far smaller processing than when each of the carriers is processed separately, thereby achieving a more rapid processing.

In a case in which the OFDM is used, the modulation timings of the modulation signals of each carrier need to be synchronous with each other. However, descending channels from the base station to the mobile stations are synchronous with each other for the base station to transmit signals thereto at a time, therefore there being no problem. Although ascending channels from the mobiles stations to the base station need to be synchronous between the respective mobile stations, the carriers allocated to the respective mobile stations are sent all at once and can be synchronous, therefore there being no problem. Further, in order compensate for an individual transmission delay among the respec-

tive mobiles stations with respect to the ascending channels, each of the mobile stations conducts time alignment for adjusting transmission time. This enables synchronization of modulation timing among the respective mobiles stations, therefore there being no problem.

The multi-carrier modulation section 11 may divide the carrier modulation user signals as shown in FIGs. 9, 11.

For example, FIG. 9 shows a case of allocation of a relatively wide frequency band. FIG. 10 shows a case of allocation of a relatively narrow frequency band. However, if the frequency band to be allocated is narrow, it can be also operated suitably for that limitation. For example, in a case shown in FIG. 11, the transmission rate to be allocated to a single user can be made especially wide so that there is no limitation with respect to maximum transmission speed for service.

Because the communication resource allocation method and apparatus according to the present invention is capable of separating the carriers between the respective users through a filter, it can suppress an interference from the other users sufficiently, thereby making it possible to prevent deterioration of S/N characteristics. The number of users which can be multiplexed is not limited by an interference from the other users, and can be freely determined depending on the band width to be allocated, obtaining to its maximum extent. By changing the number of the carriers to be allocated to users, it is possible to change transmission rate or achieve a variable rate. Further, it is possible to arbitrarily set the guard band by placing a carrier having 0 power. If the OFDM is used in multi-carrier modulation, the guard band is not needed between the carriers of different users, thereby making it possible to raise frequency availability. Because rapid Fourier transformation can be utilized, the necessary processing can be small with a rapid processing. Further, system bands allocated to, for example, 5M Hz, 10M Hz, 20M Hz or the like can be operated individually with flexibility. Further, there is no limitation in maximum bit rate which can serve for users and how the maximum bit rate which can serve for users can be changed is determined depending on the band to be allocated. Whatever the system band is, it is possible to realize communication with a narrower band. That is, even if the system band is allocated to 5M Hz or 10M Hz, communication with a narrower band is possible, so that upper compatibility can be realized.

Further, the present invention can be applied to machines and equipment in various fields.

FIG. 12 is a diagram showing a case in which the present invention is applied to broadcasting equipment. The operation thereof is substantially the same as the above embodiments. FIG. 13 is a diagram showing a broadcasting receiver. This can be applied to TV broadcasting, radio broadcasting or the like and further to ground wave broadcasting and satellite broadcasting. FIG. 14 is a diagram showing a communication terminal apparatus. The present invention can be applied to cellular phones which will be substituted for conventional GSM, PCS, PHS or the like. FIG. 15 is a diagram showing an example of base station equipment corresponding to a mobile station such as a cellular phone or the like. Here, waves transmitted from a plurality of the mobile stations are connected to circuit network. FIG. 16 is a diagram showing an example of a computer apparatus for accessing an internet or the like through optical fiber or telephone line or the like. The present invention can be applied to communications other than radio transmission. FIG. 17 is a diagram showing an example of a network server to be connected to internet or the like. FIG. 18 shows a case of application of the present invention to internet shown in FIGs. 16, 17. As the case of so-called asymmetric digital subscriber line (ADSL), ascending and descending bands can be provided on a conventional telephone band by the BDMA system.

Claims

1. A communication resource allocation method comprising:

    allocating plural carriers continuously in a predetermined band; and
    allocating some numbers of said carriers continuously as a carrier group in accordance with information to be transferred.

2. A communication resource allocation method as claimed in claim 1, wherein said plural carriers are orthogonal each other.

3. A communication resource allocation method as claimed in claim 1 or 2, wherein said plural carriers contain at least one power reduced carrier located between some carrier group and another carrier group.

4. A communication resource allocation method as claimed in any one of the preceeding claims, wherein said numbers of allocating said carriers is varied in time according to an information to be transferred.

5. A communication resource allocation apparatus comprising allocating means for allocating some numbers of carriers continuously as a carrier group in a plural carriers allocated continuously in a predetermined band in accord-

ance with information to be transferred.

6. A communication resource allocation apparatus as claimed in claim 5, wherein said plural carriers are orthogonal each other.

7. A communication resource allocation apparatus as claimed in claim 5 or 6, wherein said plural carriers contain at least one power reduced carrier located between some carrier group and another carrier group.

8. A communication resource allocation apparatus as claimed in any one of claims 5 to 7, wherein said numbers of allocating said carriers is varied in time according to an information to be transferred.

9. A transmitting method comprising:

   performing a communication resource allocation method according to any one of claims 1 to 4; and
   transmitting said allocated carriers.

10. A transmitting apparatus comprising:

   a communication allocation resource apparatus according to any one of claims 5 to 8; and
   transmitting means for transmitting said allocated carriers.

11. A receiving method including demodulating continuous plural carriers in a predetermined band in a received signal as a carrier group.

12. A receiving method comprising demodulating continuous plural orthogonal carriers in a predetermined band in a received signal as a carrier group.

13. A receiving apparatus including demodulating means for demodulating continuous plural carriers in a predetermined band in a received signal as a carrier group.

14. A receiving apparatus comprising demodulating means for demodulating continuous plural orthogonal carriers in a predetermined band in a received signal as a carrier group.

15. A transmitting and receiving method comprising:

   a transmitting method according to claim 9; and
   a receiving method according to claim 11 or 12.

16. A transmitting and receiving method as claimed in claim 15, wherein said predetermined band is a part of a maximum capacity of the communication line, and the other signal is transferred on a band of the other part of said communication line.

17. A communication subscriber apparatus comprising:

   a transmitting apparatus according to claim 10; and
   a receiving apparatus according to claim 13 or 14.

18. A communication subscriber apparatus as claimed in claim 17, wherein said predetermined band is a part of a maximum capacity of the communication line, and the other signal is transferred on a band of the other part of said communication line.

19. A communication base station apparatus comprising:

   a transmitting apparatus according to claim 10; and
   a receiving apparatus according to claim 13 or 14.

20. A communication base station apparatus as claimed in claim 19, wherein said predetermined band is a part of a maximum capacity of the communication line, and the other signal is transferred on a band of the other part of

said communication line.

FIG.1A

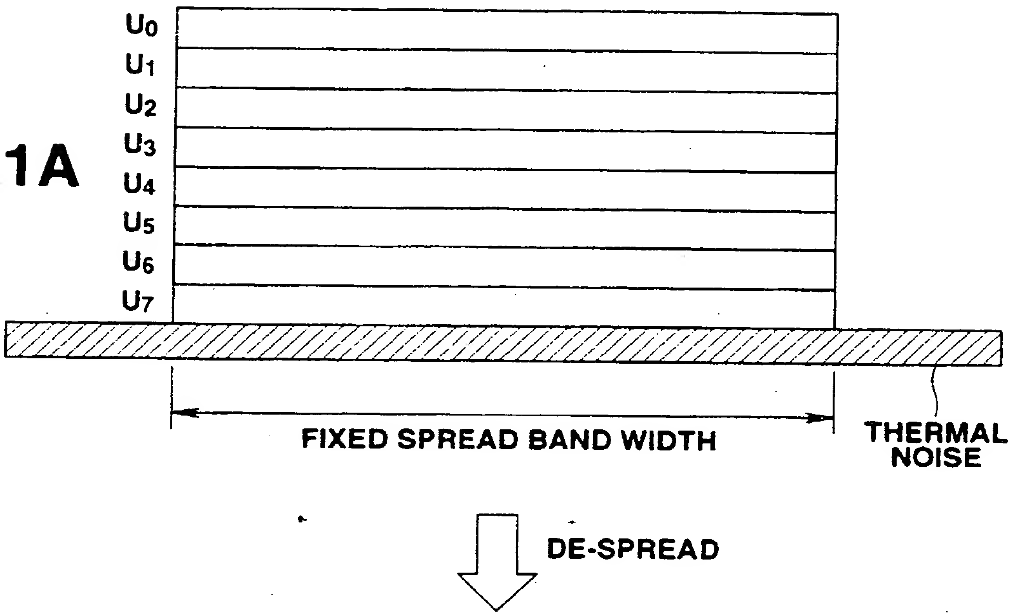
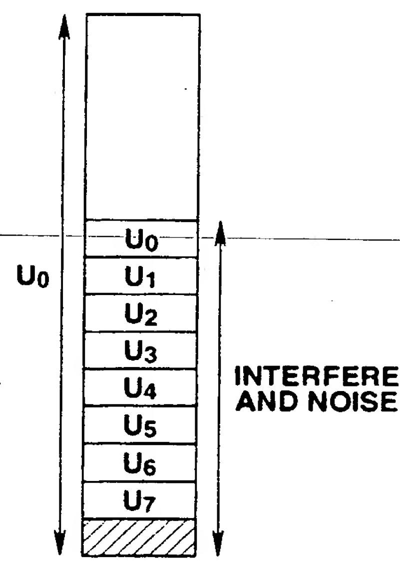

U0
U1
U2
U3
U4
U5
U6
U7
FIXED SPREAD BAND WIDTH
THERMAL NOISE
DE-SPREAD

FIG.1B


U0
U0
U1
U2
U3
U4
U5
U6
U7
INTERFERE AND NOISE

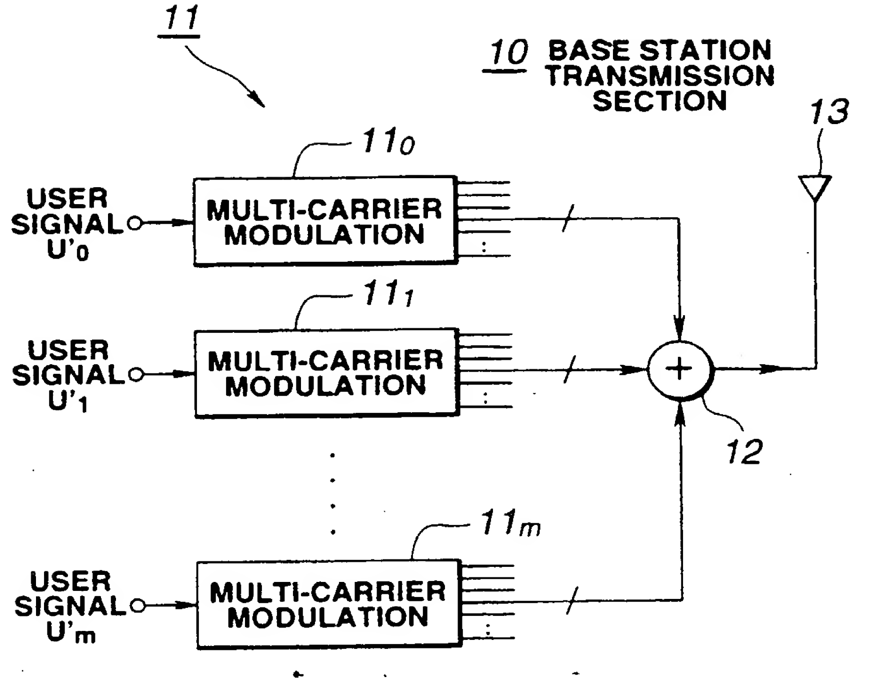

11
10 BASE STATION TRANSMISSION SECTION
13
11₀
USER SIGNAL U'₀
MULTI-CARRIER MODULATION
11₁
USER SIGNAL U'₁
MULTI-CARRIER MODULATION
12
11m
USER SIGNAL U'm
MULTI-CARRIER MODULATION

FIG.2

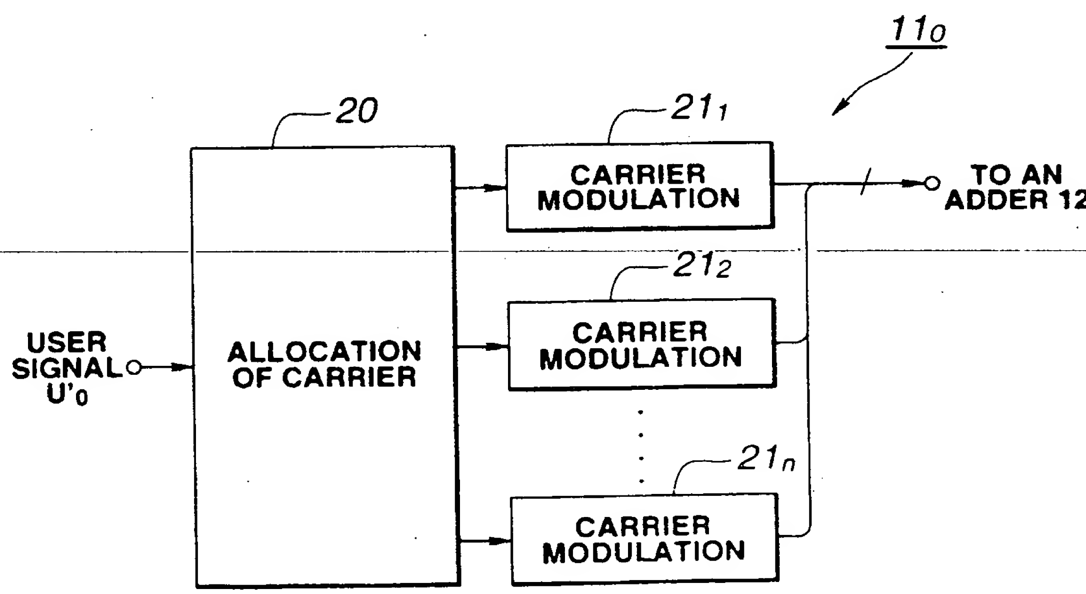

11₀
20
21₁
CARRIER MODULATION
TO AN ADDER 12
21₂
USER SIGNAL U'₀
ALLOCATION OF CARRIER
CARRIER MODULATION
21n
CARRIER MODULATION

FIG.3

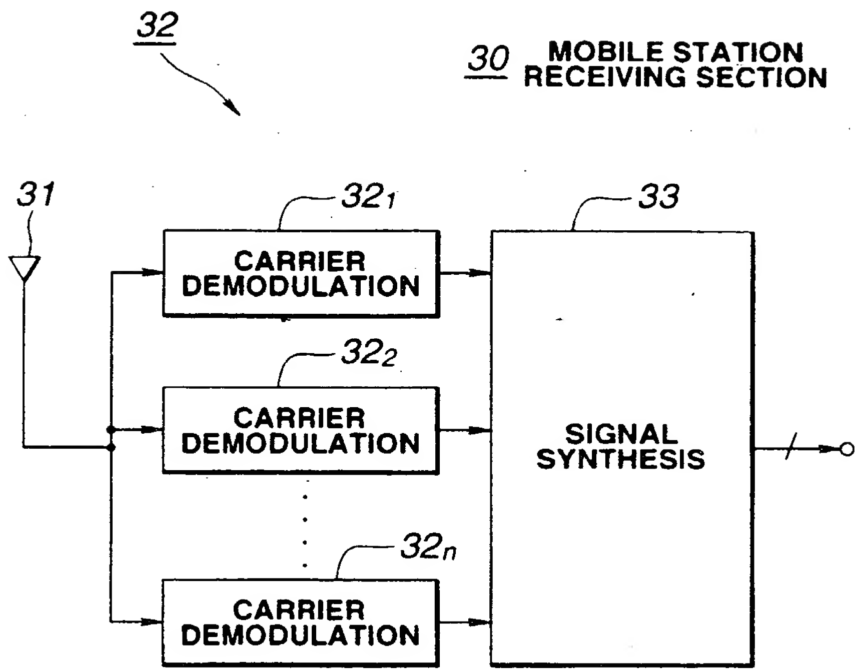

32
30 MOBILE STATION RECEIVING SECTION
31
32_1
CARRIER DEMODULATION
32_2
CARRIER DEMODULATION
32_n
CARRIER DEMODULATION
33
SIGNAL SYNTHESIS

FIG.4

FIG.5A

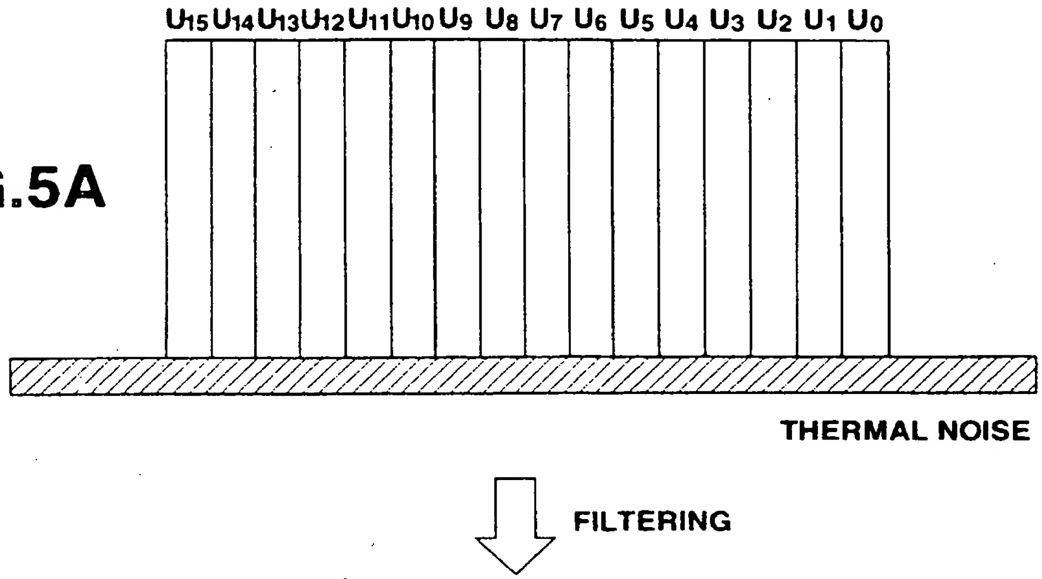

U_{15} U_{14} U_{13} U_{12} U_{11} U_{10} U_9 U_8 U_7 U_6 U_5 U_4 U_3 U_2 U_1 U_0
THERMAL NOISE
FILTERING

FIG.5B

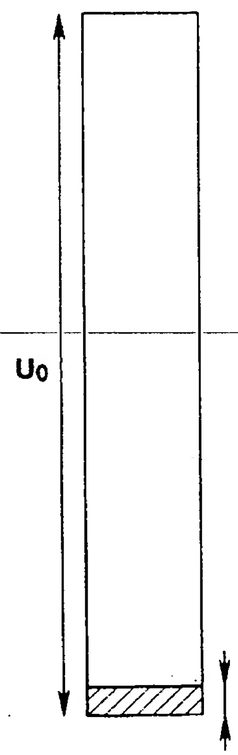

U_0
NOISE

FIG.6A

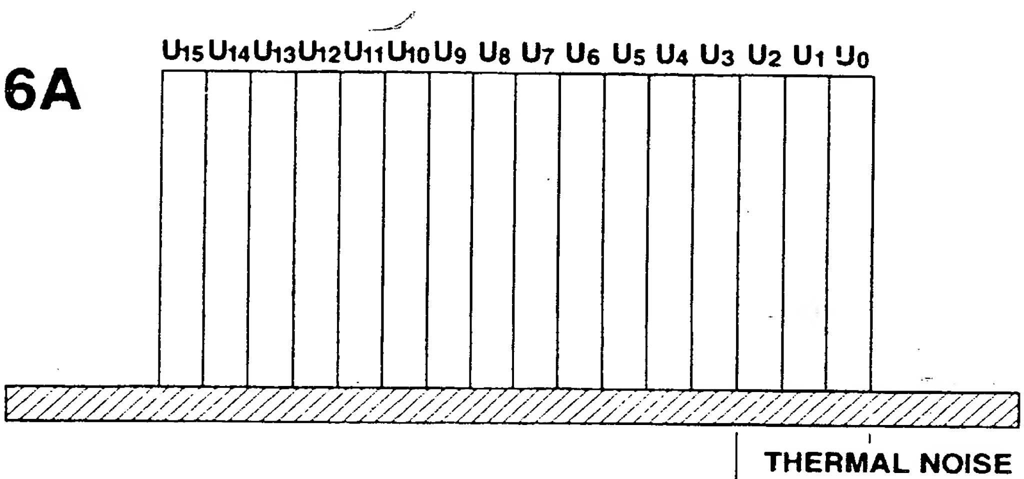
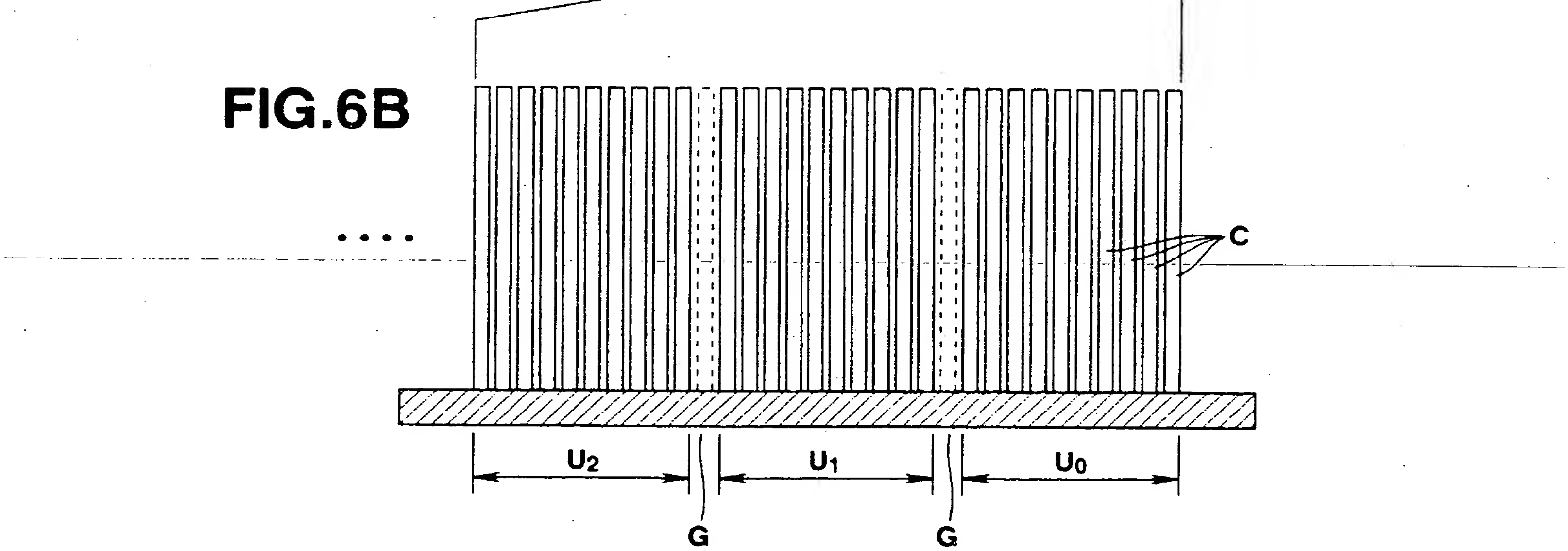


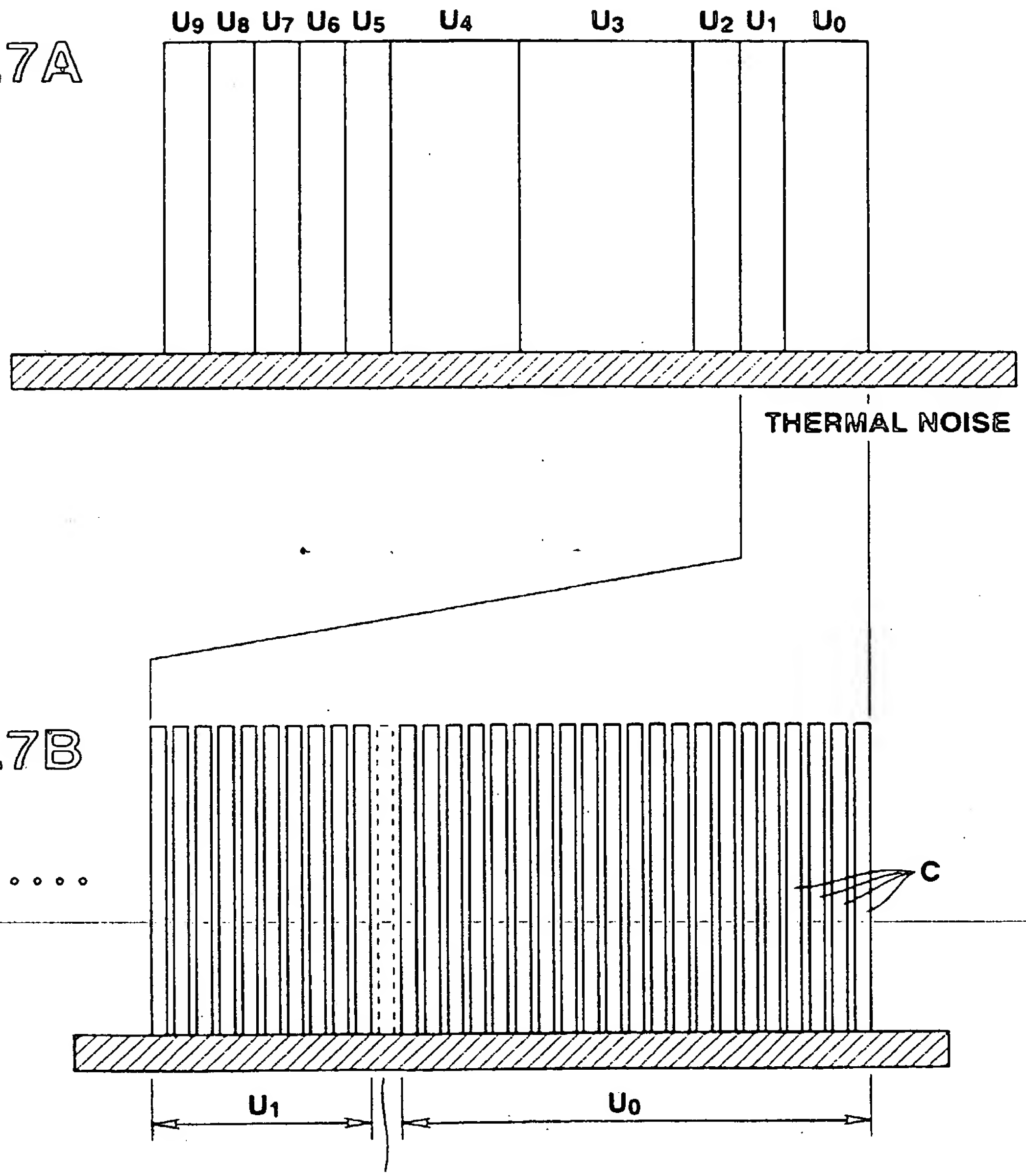
FIG.6B



C : CARRIER
G : GUARD BAND(CARRIER)

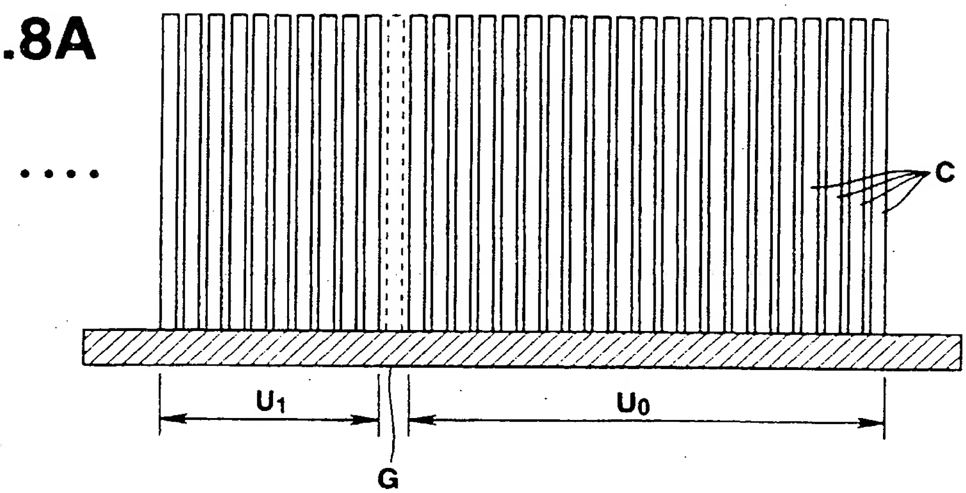
FIG.7A

FIG.7B



C : CARRIER
G : GUARD BAND(CARRIER)

FIG.8A



C : CARRIER
G : GUARD BAND(CARRIER)

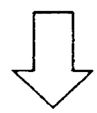
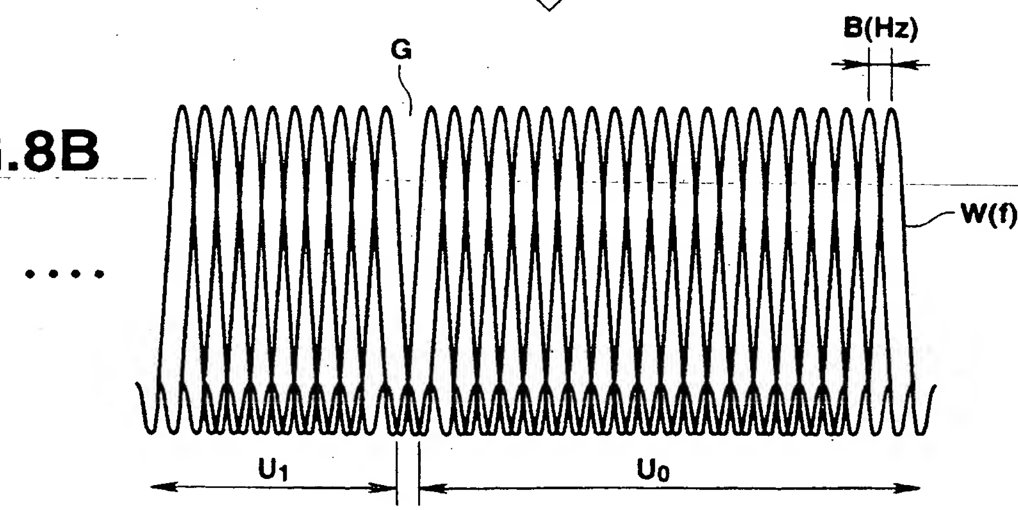


FIG.8B



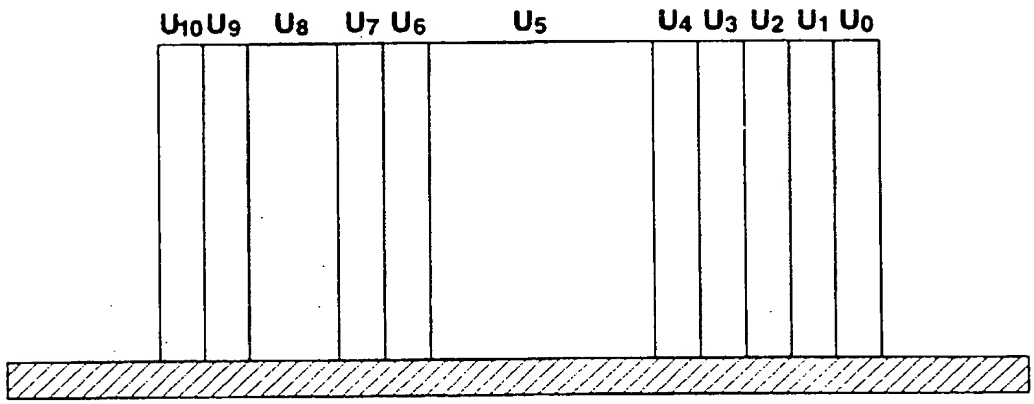


FIG.9

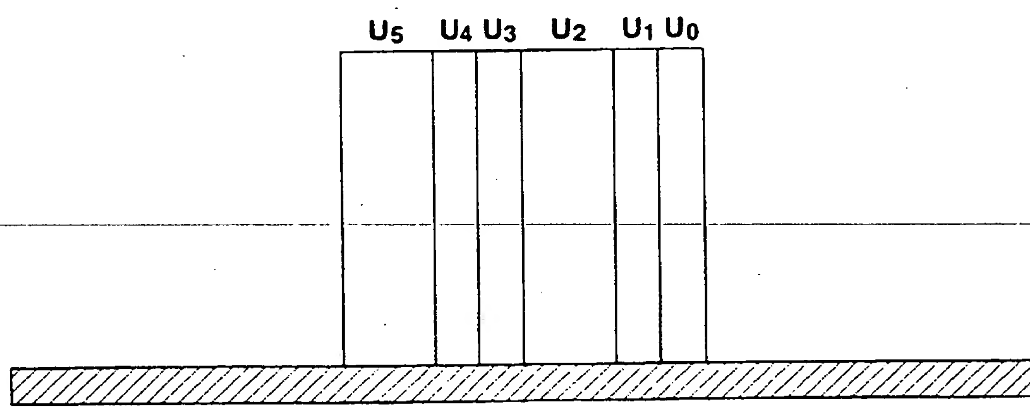


FIG.10

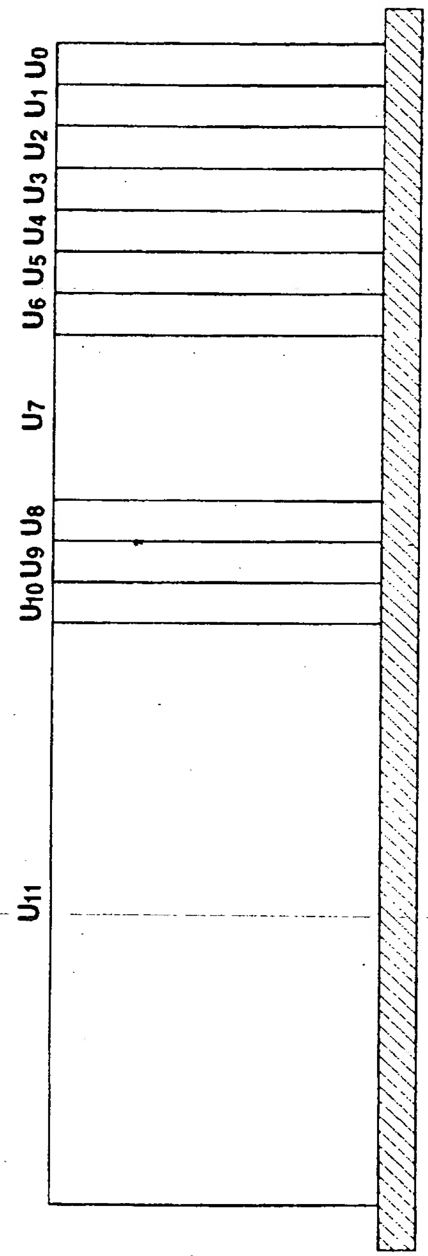


FIG.11

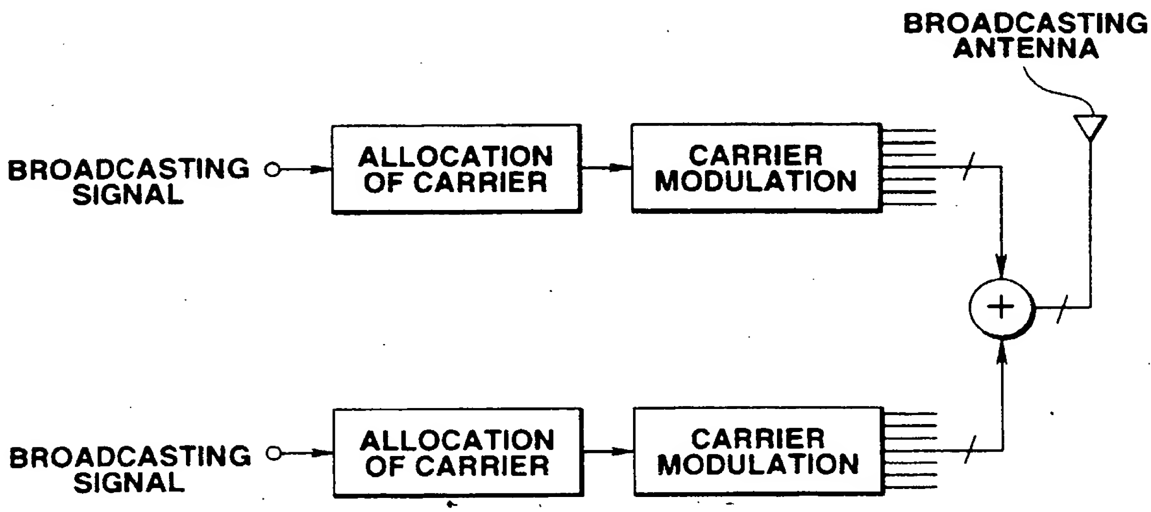

BROADCASTING ANTENNA
BROADCASTING SIGNAL
ALLOCATION OF CARRIER
CARRIER MODULATION
BROADCASTING SIGNAL
ALLOCATION OF CARRIER
CARRIER MODULATION

FIG.12

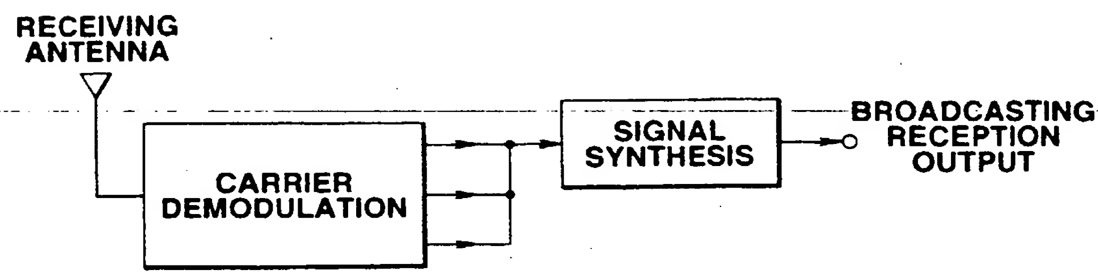

RECEIVING ANTENNA
CARRIER DEMODULATION
SIGNAL SYNTHESIS
BROADCASTING RECEPTION OUTPUT

FIG.13

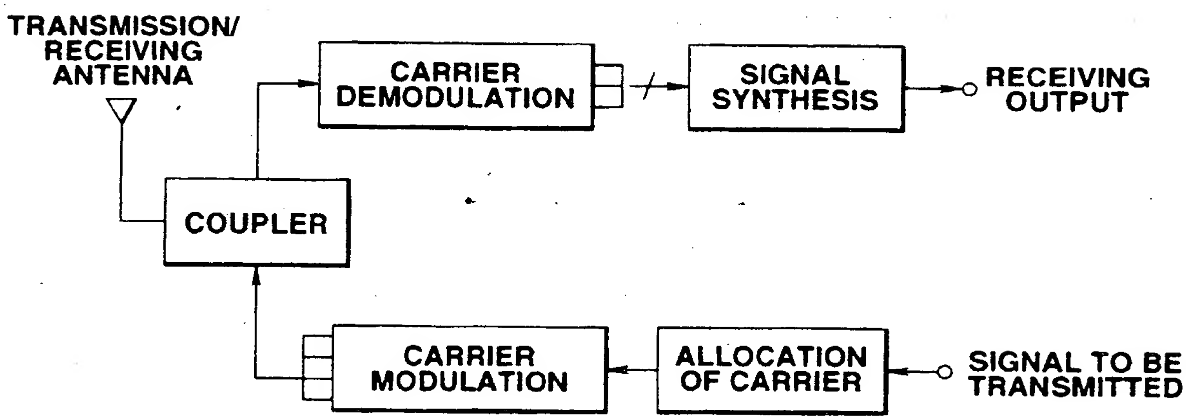

TRANSMISSION/
RECEIVING
ANTENNA
CARRIER
DEMODULATION
SIGNAL
SYNTHESIS
RECEIVING
OUTPUT
COUPLER
CARRIER
MODULATION
ALLOCATION
OF CARRIER
SIGNAL TO BE
TRANSMITTED

FIG.14

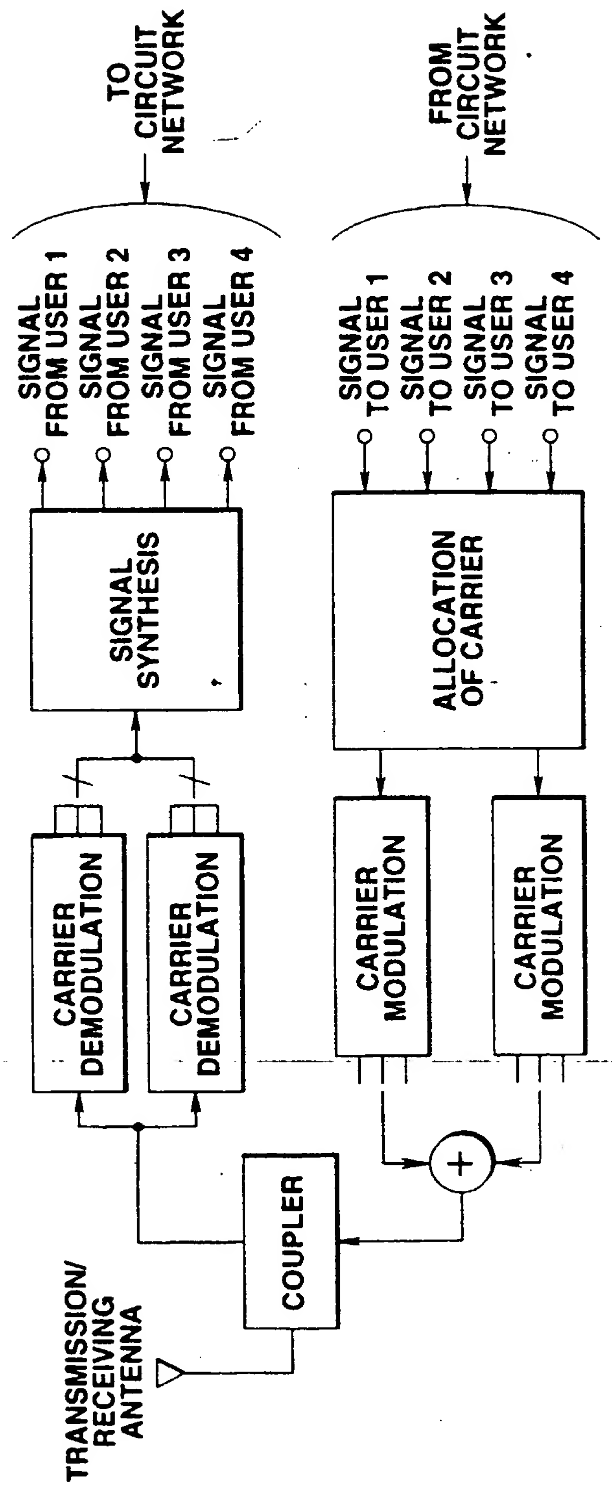

TO CIRCUIT NETWORK
FROM CIRCUIT NETWORK
SIGNAL FROM USER 1
SIGNAL FROM USER 2
SIGNAL FROM USER 3
SIGNAL FROM USER 4
SIGNAL TO USER 1
SIGNAL TO USER 2
SIGNAL TO USER 3
SIGNAL TO USER 4
SIGNAL SYNTHESIS
ALLOCATION OF CARRIER
CARRIER DEMODULATION
CARRIER DEMODULATION
CARRIER MODULATION
CARRIER MODULATION
+
COUPLER
TRANSMISSION/ RECEIVING ANTENNA

FIG.15

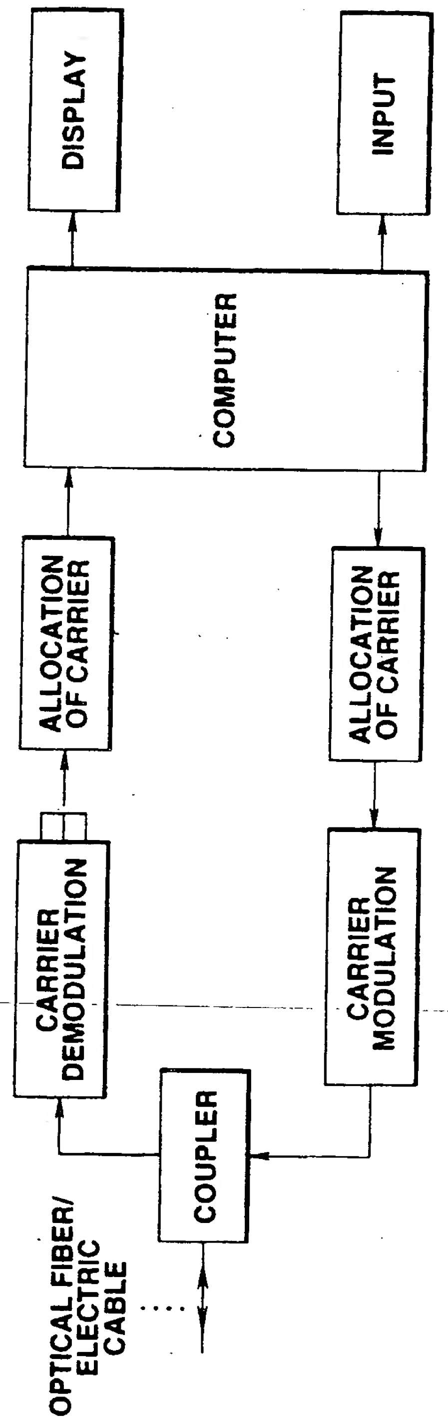

DISPLAY
INPUT
COMPUTER
ALLOCATION OF CARRIER
ALLOCATION OF CARRIER
CARRIER DEMODULATION
CARRIER MODULATION
COUPLER
OPTICAL FIBER/ ELECTRIC CABLE

FIG.16

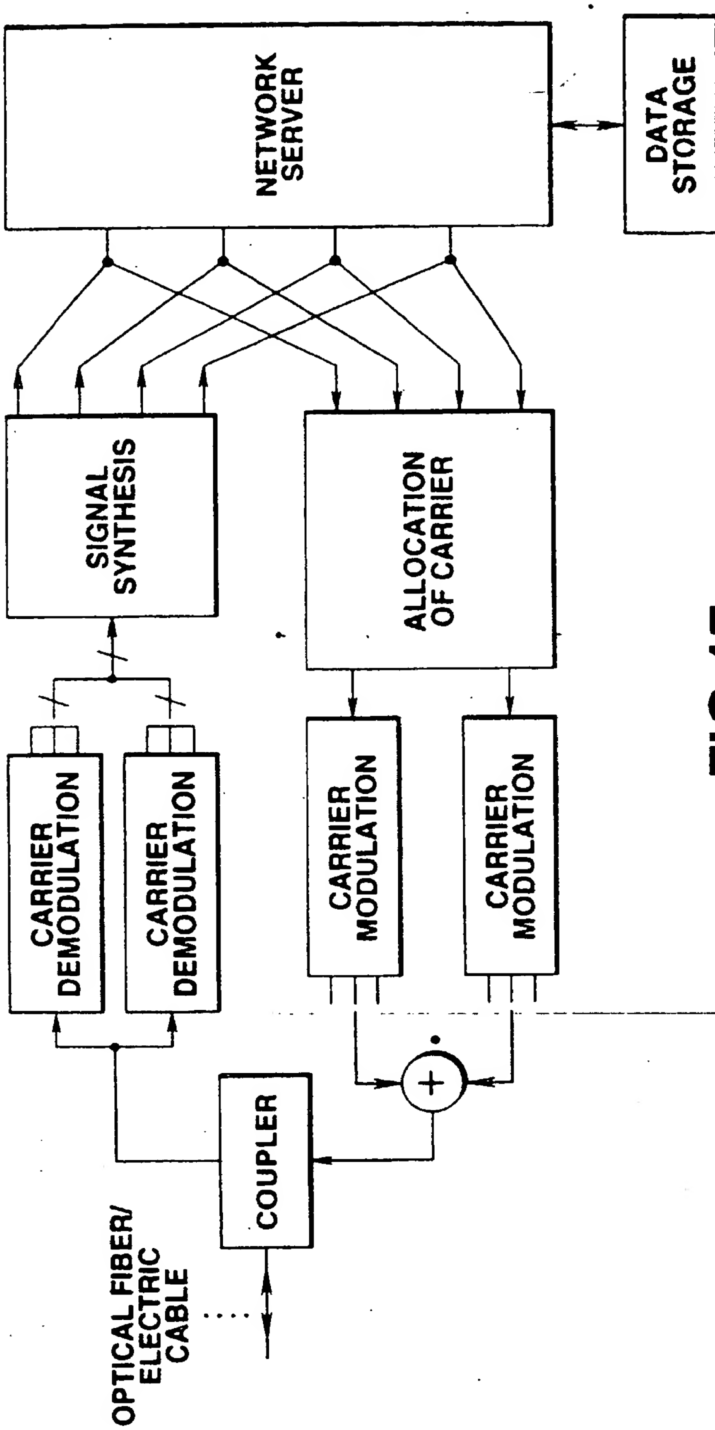

NETWORK SERVER
DATA STORAGE
SIGNAL SYNTHESIS
ALLOCATION OF CARRIER
CARRIER DEMODULATION
CARRIER DEMODULATION
CARRIER MODULATION
CARRIER MODULATION
COUPLER
OPTICAL FIBER/ ELECTRIC CABLE

FIG.17

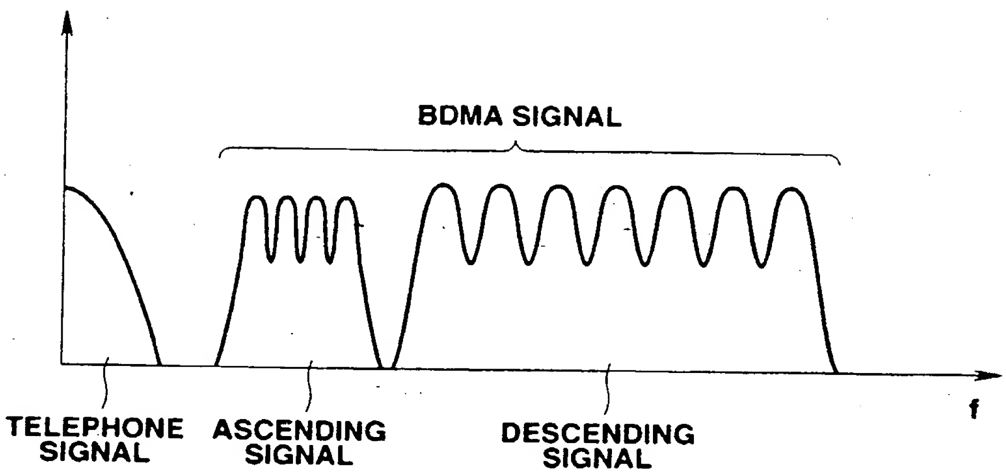

BDMA SIGNAL
f
TELEPHONE SIGNAL
ASCENDING SIGNAL
DESCENDING SIGNAL

FIG.18